

TITAN IV



Air Force ACAT IC Program

Total Number of Systems:	39
Total Program Cost (TY\$):	\$17.6B
Average Unit Cost (TY\$):	\$450M
Initial Launch Capability	3QFY89
Titan IVB ILC:	2QFY97

Prime Contractor

Lockheed Martin

SYSTEM DESCRIPTION & CONTRIBUTION TO JOINT VISION 2010

Titan IV, which evolved from earlier members of the Titan family, provides the heavy lift space launch capability to place the nation's highest priority DoD space systems and other missions into a variety of earth orbits. Titan IV is a multi-stage launch vehicle consisting of a two-stage core and a pair of large solid rocket motors attached. An upper stage placed above the main booster core is used for some missions to provide additional payload-to-orbit capability. Titan IV upper stages are of two kinds: the Inertial Upper Stage and the Centaur.

The original Titan IV design, now known as Titan IVA, employs solid rocket motors manufactured by United Technologies. Titan IVA can place up to 31,100 pounds into a polar low earth orbit. With the Centaur upper stage, Titan IVA can lift 10,350 pounds into a geosynchronous earth orbit. An improved Titan IV design, designated Titan IVB, made its maiden flight in February 1997. Improvements to the Titan IVB vehicle include the solid rocket motor upgrade manufactured by Alliant Techsystems, new guidance and avionics, standardized payload interfaces, and a new flight termination

system. Titan IVB's demonstrated lift capacity to low earth orbit is 40,000 pounds. Titan IVB with Centaur can place 13,250 pounds into geosynchronous earth orbit.

The Air Force operates Titan IV launch complexes at Cape Canaveral Air Station, FL, and Vandenberg Air Force Base, CA. As the nation's heavy lift space launch system, Titan IV is an example of *technological innovation* used to secure our nation's assured access to space. Titan IV delivers payloads to precise orbits, executing *full-dimensional protection* through the high ground of space.

BACKGROUND INFORMATION

Titan IV development was authorized by National Security Decision Directive 164 to ensure heavy lift access to space comparable to space shuttle payload capacity. Titan IV development began with a contract award to Martin Marietta (now Lockheed Martin) in February 1985. Titan IV is an outgrowth of the Titan family of intercontinental ballistic missiles and the Titan 34D medium-payload launch vehicle. Initial launch capability was achieved with the first launch in June 1989. The Titan IVB/solid rocket motor upgrade program was initiated in 1987 to improve payload performance and system reliability. Titan IVB initial launch capability was achieved with the first Titan IVB launch in February 1997. Twenty-two Titan IVA and six Titan IVB launches have been conducted up to August 1999, with 24 of the flights successful. There have been two launch failures associated with each of the two Titan IV variants.

TEST & EVALUATION ACTIVITY

Titan IV has experienced 4 launch failures in 28 launch attempts (Titan IVA on August 2, 1993 and August 12, 1998; Titan IVB on April 9, 1999 and April 30, 1999). The 1993 failure occurred after approximately 100 seconds of flight. The cause of the mishap was a solid rocket motor case burn through resulting from extensive restrictor repairs. The restrictor repair process uses a cutting tool to produce continuous cuts through the restrictor into the propellant. Cuts in the propellant that extended radially from the bore to the case, and a potting process that did not completely fill the cuts, were determined to be the source of the case burn through. All elements of the launch vehicle were exonerated except Solid Rocket Motor 1 segment 3.

The 1998 failure occurred on the final flight of the Titan IVA vehicle when the rocket exploded approximately 42 seconds after liftoff. The Air Force accident investigation board attributed the failure to intermittent electrical shorts that caused the mission guidance computer to perform a power-off reset. While the guidance computer was off line, an inertial measurement unit's gimbal position drifted. When the mission guidance computer returned to operational status, it read the gimbal's position as indicating a vehicle pitch of 26 degrees up and yaw of 5 degrees left. The computer commanded corrections placed aerodynamic stresses on the vehicle that exceeded its structural limits. The exact location and cause of the electrical shorts could not be determined. However, extensive investigation of the flight data, testing, analysis, and examination of recovered hardware led the investigation board to determine that the Stage II electrical harness had been damaged in one of nine possible locations. The damage occurred either during initial installation or rework at the launch site. Vibration and buffeting action during the flight brought the damaged electrical harness into contact with metal parts of the airframe, causing the shorts.

The Titan IVB program experienced two launch failures in April 1999, neither of which was attributed to a failure of the Titan IVB rocket. On April 9, 1999, a Titan IVB flight functioned normally

for 6 hours and 28 minutes, several hours beyond main rocket and upper stage separation. However, the Defense Support Program satellite was stranded in a useless orbit when the Inertial Upper Stage failed to execute its burn properly. The upper stage failure was attributed to the failure of an electrical plug/jack to disconnect when the first stage of the inertial upper stage attempted to separate from the second stage. The plug/jack failed to disconnect because its internal separation mechanisms were disabled due to the introduction of thermal wrapping and the misalignment of its separation connector. Engineering tests conducted during the accident investigation showed that these two factors combined were capable of inducing the failure.

The April 30, 1999 Titan IVB accident investigation board concluded that faulty Centaur upper stage software development, testing and quality assurance process failed to detect and correct a human error made during manual entry of data values into the Centaur's flight software file. Loaded with the incorrect software value, the Centaur lost all attitude control. The reaction control system of the upper stage attempted to correct these errors and fired excessively until it depleted its hydrazine fuel. As a result, the Centaur went into a very low orbit and the Milstar satellite separated from the Centaur in a useless final orbit. Air Force Space Command declared the satellite a complete loss on May 4.

With 24 successes in 28 attempts, the overall Titan IVA and IVB program operational mission reliability is 86 percent compared to the Operational Requirements Document requirement of 96 percent. The Titan IVA program concluded operations with a 91 percent mission success rate. The Titan IVB program currently has a 67 percent launch success rate based on the six launches; however, neither of the two failures have been attributed to problems with the Titan IVB rocket.

DOT&E continues to monitor launch rates, mission success rates and overall program progress. However, there are no dedicated operational tests planned for the remainder of the Titan IV program.

The Program Office completed Y2K certification by having the launch contractors and the Aerospace Corporation test or analyze the Titan IV rocket, subsystems, critical interfaces, and support equipment. The Air Force Program Executive Officer for Space certified the systems Y2K compliant in September 1998. The certification letter noted that two software items in a critical ground system were not compliant but were acceptable due to operational workarounds. Those two software items have since been upgraded, tested, and found to be Y2K compliant. Additionally, a new Centaur ground computer system being installed at Cape Canaveral will replace a non-Y2K compliant legacy system. System installation, checkout, and Y2K certification will be completed in early December 1999.

TEST & EVALUATION ASSESSMENT

The Titan IV program has demonstrated that it is capable of effectively placing its assigned payloads into the required payloads when all systems perform nominally. However, reliability issues continue to plague the program. Before the most recent series of failures, reliability shortfalls were small and the trends were positive. Mission success rate is now well below requirements and stands out as the program's major shortfall. Over \$2 billion in payloads and launch vehicles have been lost between August 1998 and April 1999. On the positive side, the two Titan IVB mission failures were not attributed to the rocket (Titan IVA failures were rocket failures). However, the existence of at least three different mission failure modes in three launches raises serious questions regarding the ability of the current quality control, checkout, and other procedures to ensure that only mission ready hardware and software are certified for future launches.

CONCLUSIONS, RECOMMENDATIONS, LESSONS LEARNED

Several Air Force, Department of Defense, and aerospace industry broad-area reviews have been initiated in response to the failures of the Titan and other U.S. launch vehicles. Their recommendations regarding changes to design, manufacture, assembly, test and other facets of launch have yet to emerge. Having full faith in these panels and the accident investigation teams, DOT&E has no plans to conduct an independent evaluation of Titan operations at this time. For the present, DOT&E will maintain communications with the Titan IV program office, monitor Titan IVB operations, evaluate recommendations from the broad-area reviews, and offer recommendations whenever that will prove helpful to the success of the Titan IV program.

Titan IV operations offer many potential lessons for the Evolved Expendable Launch Vehicle programs under development. In light of the recent problems and ongoing broad-area reviews, these lessons may prove particularly helpful in avoiding design, quality control, and vehicle checkout problems.